Falwitz Contract

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ELECTRO-OPTICAL SYSTEMS, INC. Pasadena, California

#7

Monthly Progress Report
27 January - 27 February 1963

RESEARCH PROGRAM RELATED TO VAPOR THERMIONIC CONVERTERS FOR NUCLEAR APPLICATION

Prepared for:

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Space Electric Power Office
21000 Brookpark Road
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Contract NAS 3-2529

EOS Report 3410-ML-4 11 March 1963

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CONTENTS

ILLUSTRATIONS

1. INTRODUCTION

This is the fourth monthly letter report of progress on Contract NAS 3-2529, a research program related to vapor thermionic converters for nuclear application.

The majority of this last reporting period was allotted to the continuing fabrication and assembly of test vehicles, to the identification of crystal planes on a 100 hour grain growth specimen, and to the vacuum processing of emitter test samples. A description of the program status of various tasks, the program for the next interval, the financial status, and quantitative description of progress are contained in the following text.

2. PROGRAM STATUS

2.1 Sample Processing Investigation

All test specimens from molybdenum bar and flat stock have been machined, polished flat to within 1/10th wavelength of the mercury green line, and chemically cleaned in accordance with Appendix A of the first quarterly report (EOS Report 3410-Q-1) on this contract.

Nine plate stock specimens have been vacuum processed as indicated in Table 2-1 and are presently being metallographically examined. Process treatment of test specimens has been described in previous reports on this study. Reviewed briefly, however, they are as follows:

a. Vacuum environment conditions at temperature are 1×10^{-6} mm Hg or lower.

b. Sample temperatures are measured with a micro-optical pyrometer. The pyrometer is frequently calibrated against a standard lamp to ensure an accuracy better than $\pm$ 10°C at 2000°C. To achieve this accuracy in temperature measurement, the hohlraum depth to diameter

TABLE 2-I

MOLYBDENUM PLATE STOCK

INVESTIGATION SAMPLES

Sample Temperature	Process Time	Vacuum Conditions
	10 minutes	8.5×10^{-7} mm Hg.
1700°C	20 minutes	8.6×10^{-7} mm Hg.
	30 minutes	4×10^{-7} mm Hg.
	10 minutes	7×10^{-7} mm Hg.
1800°C	20 minutes	4×10^{-7} mm Hg.
	30 minutes	4×10^{-7} mm Hg.
	10 minutes	4×10^{-7} mm Hg.
1900°C	20 minutes	4×10^{-7} mm Hg.
	30 minutes	4×10^{-7} mm Hg.

dimensions are in a ratio of 10 to 1. For materials such as molybdenum these hohlraum dimensions permit 99.9+ percent of true temperature to be optically observed.

2.2 Grain Growth Experiments

2.2.1 Vehicle Fabrication

Vehicles for long time grain growth studies of molybdenum in a cesium vapor environment have been constructed. A furnace, composed of a helical heat element and attendant shielding, is presently being assembled. The design calculations indicate that 40 or 50 turns of .002 inches molybdenum foil is sufficient to shield the furnace at operating temperatures of 1900°K. A filament transformer and the necessary metering equipment has been assembled to provide electrical power to the heating element.

2.2.2 Replica Studies

To perfect the X-ray diffraction techniques necessary for determining grain orientation within the plane of molybdenum bar sample, a round button of molybdenum .75" in diameter and .2" thick was sliced from molybdenum bar stock and heated 100 hours at 1800°K in vacuum. Grain size after this treatment was of the order of 1 mm average size. The recrystallized sample was carefully polished and etched with Murakami's reagent to allow the grains to be readily distinguished. To determine the orientation of an individual single crystal or grain with respect to the polished surface, it was essential that adjacent or surrounding crystals be shielded from the X-ray beam. This was accomplished by means of a shield of tantalum foil .004" thick. A hole slightly smaller than the grain to be examined was drilled through the foil prior to placing the shield over the specimen surface. To facilitate locating the hole in the shield over the grain whose orientation was to be determined, a microscope mounted on a goniometer was used to locate the particular grain to be examined and act as an aid in locating the shield.

The X-ray beam was produced by the application of 45 kilovolts to a molybdenum target tube. The angle of maximum reflected intensity was measured by means of a proportional counter tube mounted on the goniometer. From the angle of maximum reflected intensity, the single grain examined was found to have its 112 plane parallel to the surface of the specimen.

Sections across the diameter of the unrecrytallized "as received" molybdenum bars are presently being ground to a thickness of .004" for transmission diffraction studies for the plotting of "pole figures" to determine the degree of preferred orientation in the unrecrystallized material.

2.3 Cesiated Emission Investigation

The test vehicles for performing emission measurements are being fabricated. All necessary parts for the test vehicles have been machined, inspected and chemically processed.

The techniques which are necessary for fabricating the emission test vehicle have been successfully tried and are being applied to a final design of the test vehicle.

Figure 3-1 is a volt-ampere characteristic for a planar 2 cm^2 cesiated tantalum emitter at the specified conditions of operation. The sharp break in the curve is identified as the departure from space charge limited emission. This departure is taken as the true saturated emission capability of the cesiated substrate. The constant-slope of the characteristic from the break to the current axis is interpreted as Schottky effect (i.e., emission enhancement by the sheath field at the emitter surface.) This characteristic was obtained without a guard ring on the emitter. The addition of a guard ring to the structure should allow much greater definition of the break point.

The particular emitter material yielding the emission data in Figure 2-1 is plate stock tantalum with a predominant $\{110\}$ and $\{112\}$ (Ref. 1) crystal orientation. The saturated emission density for this material under conditions of high emitter temperatures and cesium arrival rates is superior to that reported for tantalum rod or wire samples as an emitter substrate. We are anticipating that the same phenomenon will be observed in emission data obtained from cesiated molybdenum bar and flat stock.

Table 3-I compares emission data from tantalum plate and bar stock. Houston's emission data from cesiated tantalum wire (Ref. 3) were taken at cesium arrival rates too low to be compared to EOS data. It is interesting to note that the emission from tantalum plate stock for an emitter temperature of 1555°C and cesium reservoir temperature of 360°C is almost twice the predicted emission from cesiated tungsten wire given by the Langmuir-Taylor theory.

In summary, we feel our vehicle designs, fabrication technology, and measuring techniques have been tested and are ready for incorporation into the final emission test vehicle. On this basis the construction and operation of the emission vehicle should proceed with only minor problems.

2.4 Electron Emission Microscope

All the major parts for the electron emission microscope have been designed and fabricated with the exception of several items where delays in delivery have been encountered. These specific items will be discussed in more detail below.

The following paragraphs discuss, in detail, the status of the more important components and sub-assemblies. The pertinent detailed engineering drawings have been appended to Section 6.

2.4.1 Cathode Assembly

The design of the emitter assembly has been completed (see Figure 2-2) and the assembly is being fabricated. The emitter assembly contains a long tantalum support tube to reduce the conduction heat loss from the emitter, layers of tantalum foil to reduce radiation loss, and a hohlraum in the emitter for temperature measurement by means of an optical pyrometer. The tantalum tube is joined to the emitter sample by means of heliarc tack welds which can be machined off to change samples.

TABLE 3-I

CESIATED TANTALUM EMISSION

Operating Conditions	E.O.S. (Processed Plate Stock)	Gibbons (Ref. 2) (Bar Stock)
$T_e = 1340^oC$ $T_{cs} = 300^oC$	3 amps/cm^2	.7 amps/cm^2
$T_e = 1392^oC$ $T_{cs} = 300^oC$	2.2 amps/cm^2	.5 amps/cm^2
$T_e = 1555^oC$ $T_{cs} = 360^oC$	30 amps/cm^2	No Data

The emitter traversing mechanism has been fabricated and is shown in Figure 2-3 with other components of the microscope. The traversing mechanism allows movement of the emitter relative to the lens by means of a flexible bellows arrangement. The emitter can be adjusted $\pm$ 1/4 inch in any direction relative to the lens. Relative displacement will be measured with a depth gauge.

2.4.2 Electrostatic Lens

Figure 2-3 also shows the assembled electrostatic lens. The first aperature plate is molybdenum to minimize contamination of the molybdenum emitter. The second electrode, in the form of a molybdenum cup is behind the first plate. The third electrode is made of oxygen free high conductivity (OFHC) copper. The first two electrodes are each attached to OFHC copper heat sinks. Since the first electrode will receive the greatest heat input, its heat sink is in thermal contact with the walls of the vacuum tank. The first two molybdenum electrodes have been designed so that they can easily be replaced with electrodes of various aperture size.

2.4.3 Phosphor Screen Assembly

The round ring structure in the background of Figure 2-3 holds the phosphor screen. It consists of two parts: a screen mount and a screen holder (Figure 2-4).

The screen mount is attached to the isolation tube (Figure 2-5), the other end of which is attached to the last electrode of the lens assembly. The purpose of the isolation tube is to provide a field free region between the lens and the screen. Such a field free region is necessary for proper operation of the lens (Ref. 4). If this tube were absent, the vacuum tank wall, being at ground potential, would prevent the formation of an image.

The screen holder has been counterbored to receive the glass screen, which is held in the holder by three flexible tabs. The phosphor screen and holder will be handled and stored as a unit to minimize possible damage to the phosphor.

The phosphor must be rugged, capable of enduring a large number of bakeout cycles, and yet be sensitive to the low electron beam densities encountered in the present studies. These requirements make the choice of a phosphor difficult. Consequently, two aluminized phosphor will be tried: a zinc orthosillicate phosphor and a zinc sulfide phosphor. The sulfide phosphor is more sensitive but less rugged than the orthosilicate phosphor.

2.4.4 Vacuum System

The microscope vacuum enclosure with its associated pumpdown line is shown in Figure 2-6. Ultek OFHC copper compression seals are used throughout the system.

The tank was delayed in its completion by 4 weeks because of trouble in welding on the large Ultek inserts at each end of the tank. The original weld configuration caused distortion of the inset, hence the weld configuration was successfully modified so as to require less heat and thus minimize distortion.

Figure 2-6 shows the three components of the pumpdown line; namely, the pinch-off line, trap, and the pumping manifold. The function of the pumpdown line is to allow evacuation of the vacuum tank during bakeout by means of an auxiliary vacuum diffusion pump station connected to the manifold (Figure 2-7). The trap (Figure 2-8) is a high conductance, low oil creep design, employing crystalline aluminosilicate pellets as a trapping material. The pellets minimize oil contamination of the vacuum tank from the diffusion pump (Ref. 5). After bakeout the copper line is pinched off and the tank removed from the auxiliary pump station. The vacion pump, which will be attached to the bottom port of the tank, will then be turned on and the sample examination begun. By using a vacuum diffusion pump only during the bakeout cycle and a vacion pump during the subsequent operation of the emitter, it is anticipated that contamination of the sample by diffusion pump oil will be minimized.

The stand, shown supporting the vacuum tank in Figure 2-3, is made of heat resistant stainless steel. Details of its construction are given in Figure 2-9.

A view port mounted on the side of the tank allows emitter temperature measurement with an optical pyrometer. The large view port on the end of the tank is for observation of the phosphor screen. The design of both these view ports (Figures 2-10 and 2-11) has been completed and presently both items are in fabrication. Westinghouse Astroelectronics Laboratory has agreed to fabricate the port in accordance with the requirements of ultra high vacuum techniques. It is expected that the view ports will be completed 2-4 weeks hence.

A high voltage cage to protect the operator has been designed (Figure 2-12) and is presently in the process of being fabricated.

2.4.5 Electrical System

Figure 2-13 shows the wiring detail for the filament power supply and the front panel of the electron bombardment supply. Both supplies have been designed and constructed to withstand 20 kilovolts between the secondary of the transformer and the chassis.

The necessary precautions which must be observed in order to insure this voltage holdoff capability, such as floating the choke and condenser, and establishing long surface leakage paths, are illustrated in Figure 2-13.

The filament supply is capable of delivering 16 amps D.C. at 10 volts with a ripple of about 2 percent. The electron bombardment supply delivers 200 milliamps D.C. at 1 kilovolt with about 2 percent ripple. The latter supply has been equipped with a zener diode circuit to protect the current meter should vacuum sparking occur.

The electrostatic lens power supply consists of three units: a 10 kilovolt-250 milliampere supply, a 15 kilovolt-5 milliampere supply, and a voltage divider network. The voltage divider network shown in Figure 10 of the first monthly report has been modified to include a current meter and protection circuit.

3. PROGRAM FOR THE NEXT INTERVAL

In the next report period we will: (1) complete the process studies and make initial comparison of the data from molybdenum plate and bar stock, (2) continue the X-ray studies of the sample surfaces in an attempt to identify crystal orientation on molybdenum grain growth samples, (3) fabricate and commence initial operation of the cesiated emission test vehicles, and the cesiated grain growth study vehicle, (4) finish fabrication and checkout of the electron emission microscope.

It is anticipated that only difficulties of a routine nature will be encountered in the next reporting period.

4. FINANCIAL STATUS

Man hours, dollar expenditures, and purchase commitments for periods ending 27 January 1963 and 27 February 1963 are submitted as a separate enclosure to this report.

5. PROGRESS DESCRIPTION

We estimate that approximately 37 percent of the program has been completed.

6. PRINCIPAL CONTRIBUTORS

The following personnel have been principal contributors to the program over the past period:

A. O. Jensen
A. E. Campbell
D. G. Worden
W. Dong
H. Todd

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5. M. A. Biondi, Rev. Sci. Inst., <u>30</u>, p. 831 (1959)

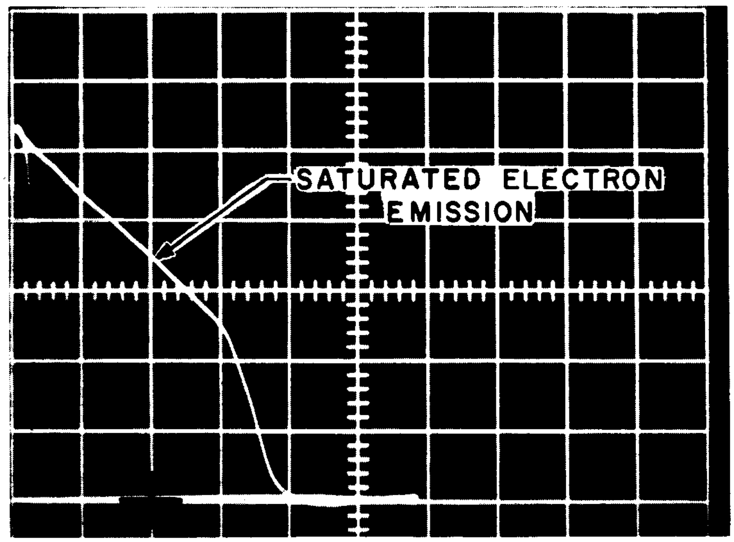


FIG. 2-1 VOLT-AMPERE CHARACTERISTIC OF CESIATED TANTALUM PLATE STOCK.

$T_e = 1205^{o}C$ $T_{coll} = 445^{o}C$ $T_{cs} = 272^{o}C$.

Vertical scale 2 amperes/div.

Horizontal scale .2 volts/div. (origin as noted)

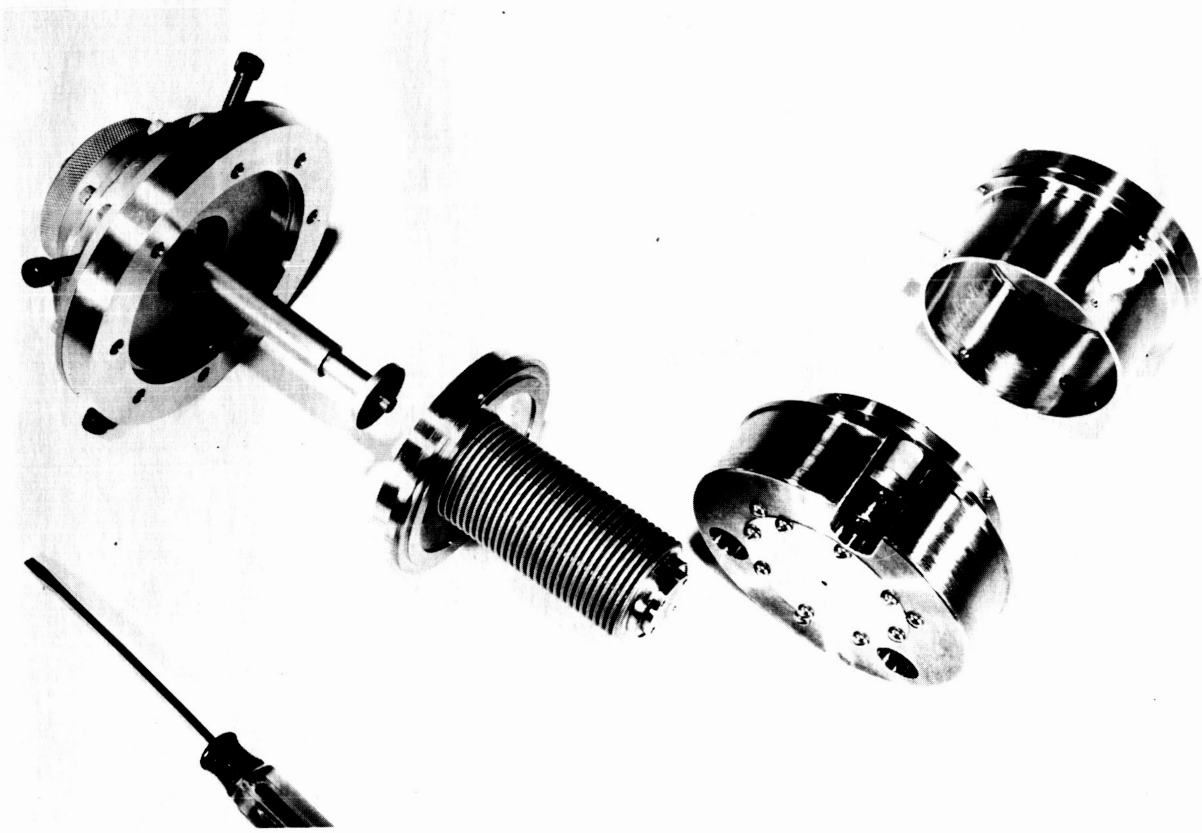


FIG. 2-3 MICROSCOPE COMPONENTS

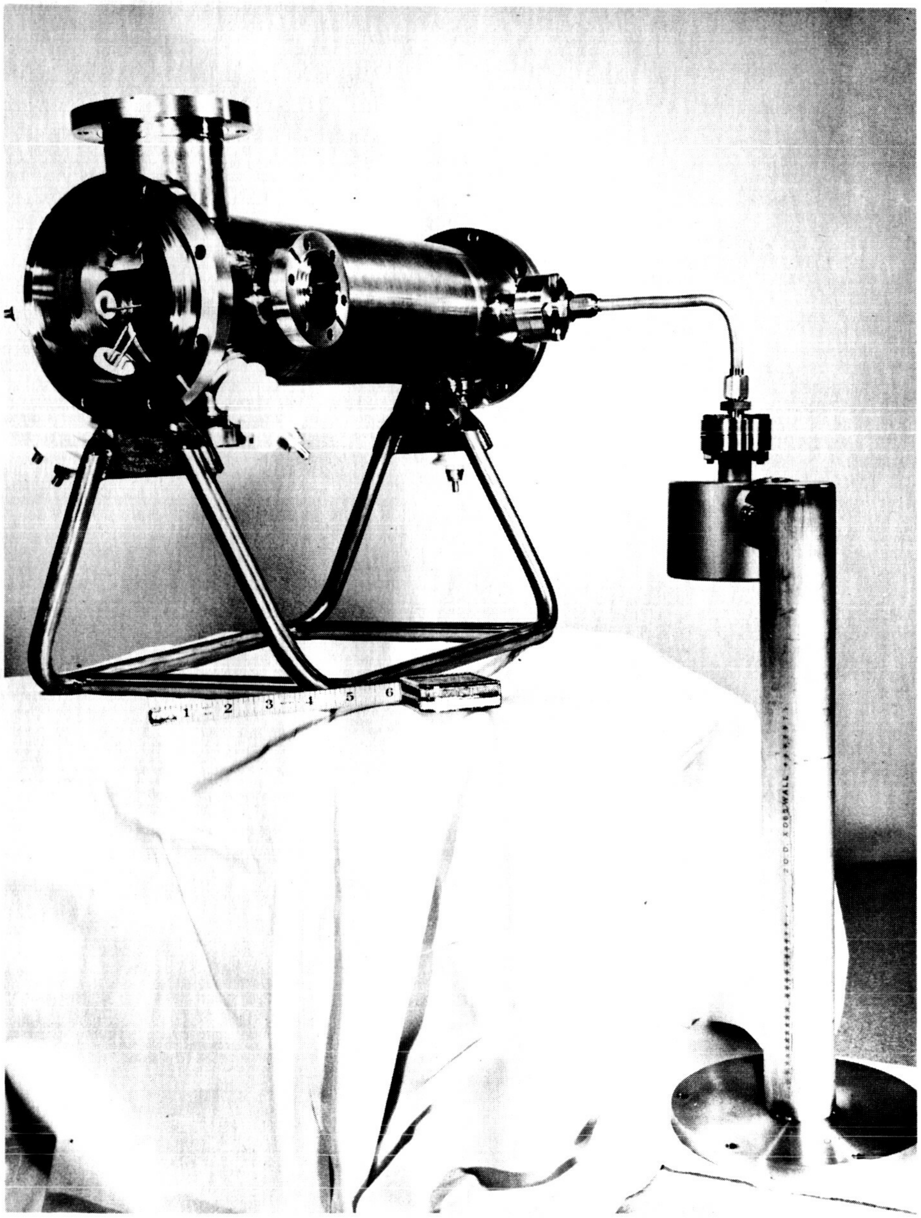
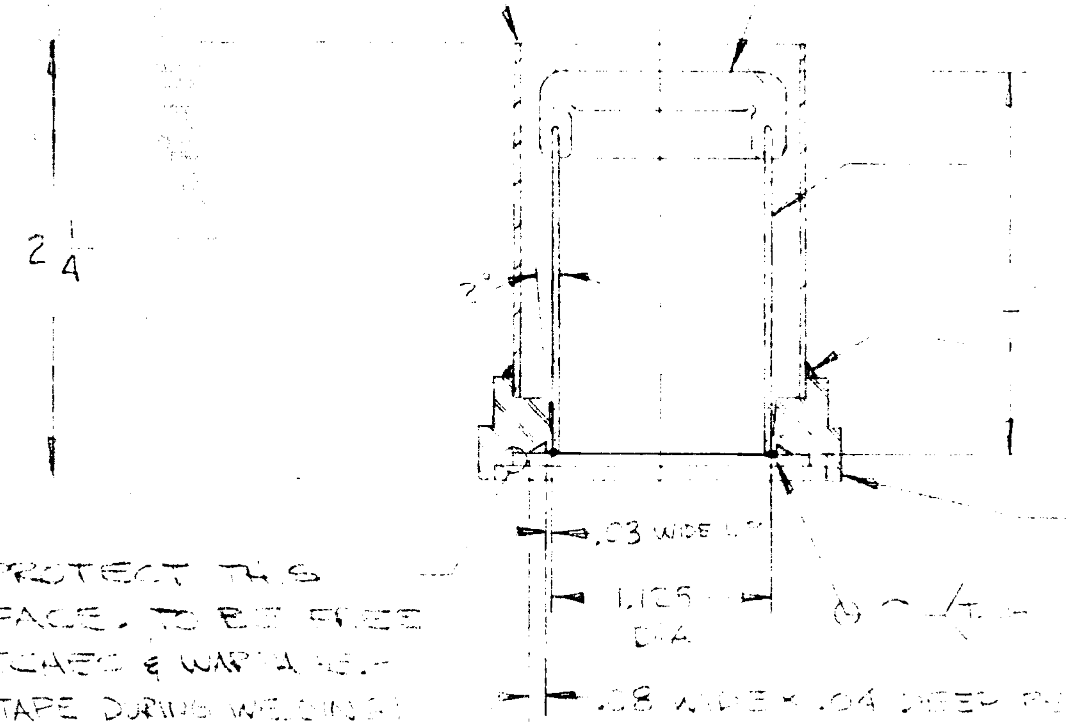


FIG. 2-6 VACUUM TANK AND EVACUATION LINE

SECURITY CLASSIFICATION

REVISIONS

CHANGE	ZONE	DESCRIPTION	BY	CHECKED	APPROVED	DATE
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
A		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]



REQ'D	ITEM	PART NO.	DESCRIPTION	SIZE	MATERIAL	SPECIFICATION

LIST OF MATERIALS

NEXT ASSY	QTY	UNIT	QTY

ORIGINAL APPLICATION

UNLESS OTHERWISE NOTED:
1. LINEAR DIMENSIONS IN INCHES.
2. TOLERANCES:
DECIMAL FRACTIONS ANGULAR
.X ± ± 1/64 ±
.XX ±
.XXX ±

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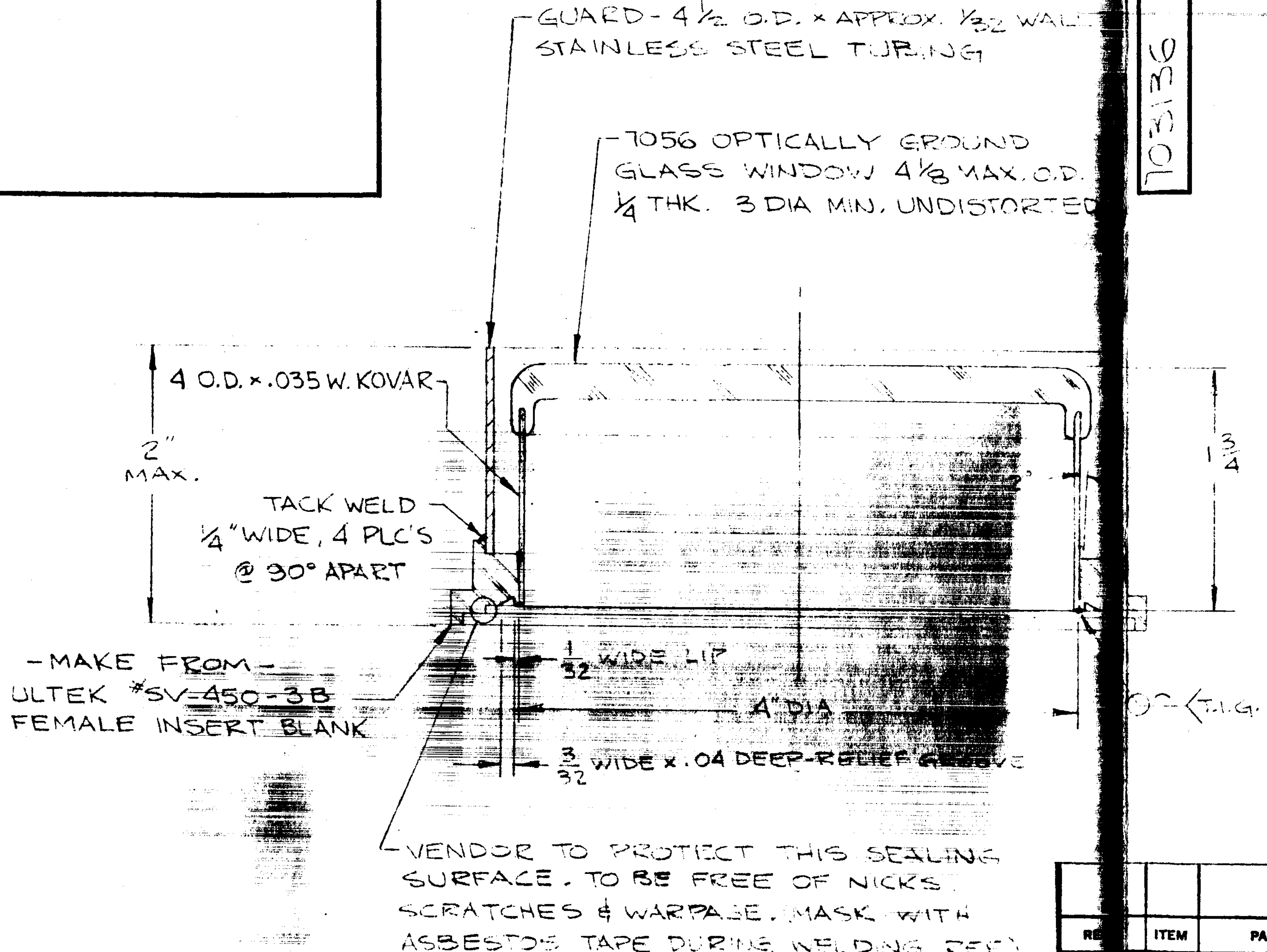
DRAWN
CHECKED
DESIGN
APPROVED
APPROVED
RELEASED
ACT. WT.
CALC. WT.
DATE

ELECTRO-OPTICAL SYSTEMS, INC.,
Pasadena, California • MUrray 1-4671, 449-1230

TITLE: FIG. 2-10
1 1/2 BAKEABLE U.H.V. WINDOW PORT

SECURITY CLASSIFICATION | SIZE B | NUMBER 703127 | REV. A
CODE IDENT NO. | SCALE | SHEET OF

EOS FORM NO. 271



103136 A

REVISIONS

CHANGE	ZONE	DESCRIPTION	BY			
		[illegible] FOR FIG 2-12	TTB			
A		ADDED NOTE 3 & 2 SHT SIZE CONFIG.	TTF			

NOTE:
1. LEAKRATE TO BE LESS THAN 1×10^{-9} STD. CC/SEC He AFTER A MINIMUM OF 15 BAKEOUT CYCLES EACH AT 400°C FOR 8 HOURS.
2. DO NOT USE SULFUR BASED OILS IN MACHINING.
3. DO NOT USE ANY ABRASIVE MACHINE TOOLS OR EMERY CLOTH.

REQ	ITEM	PART NO.	DESCRIPTION	SIZE	MATERIAL	SPECIFICATION

LIST OF MATERIALS

NEXT ASSY	QTY	UNIT	QTY

ORIGINAL APPLICATION

UNLESS OTHERWISE NOTED:
1. LINEAR DIMENSIONS IN INCHES.
2. TOLERANCES:

DECIMAL	FRACTIONS	ANGULAR
X ±	±	± ½°
XX ± .010		
XXX ± .005		

		DATE
DRAWN	[illegible]	2-13
CHECKED	W. D. DONG	2-13 65
DESIGN	[illegible]	
APPROVED	W. D. DONG	2-13 65
APPROVED		
RELEASED		
ACT. WT.	CALC. WT.	

ELECTRO-OPTICAL SYSTEMS, INC.,
Pasadena, California • MUrray 1-4671, 449-1230

TITLE: FIG. 2-11
4½" BAKEABLE U.H.V. WINDOW PORT

SECURITY CLASSIFICATION | SIZE B | NUMBER 103136 | REV. A

CODE IDENT NO. | SCALE FULL | SHEET 1 OF 1

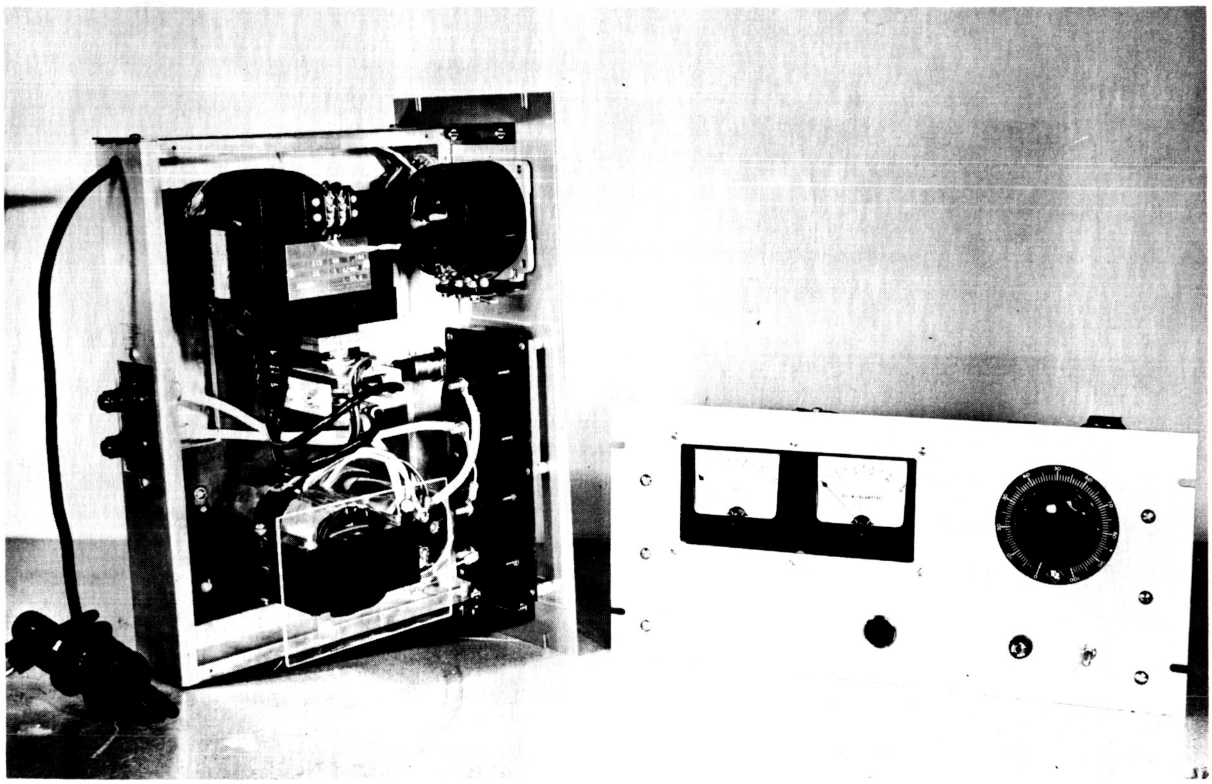


FIG. 2-13   CATHODE POWER SUPPLIES